NASA-TM-107982

NASA Lewis

7N-32-TM
117786

ACTS SYSTEM HANDBOOK
REVISION CHANGE INDEX

by Peter A. Lowry

P23

REV #	DATE	PAGES AFFECTED	NAME/GENERAL DESCRIPTION
	03/89		Date issued
1	10/11/91	v, B-24, -24A, -24B	Add description of downlink upconverter spurious signals
2	08/24/92	ii-ix, AA-1, Appendix B	Update Front Matter, Update Appendix A, Add Appendix B - Beacons

(NASA-TM-107982) ACTS SYSTEM HANDBOOK, REVISION CHANGE INDEX (NASA) 23 p

N93-70235

Unclas

Z9/32 0117786

PRECEDING PAGE BLANK NOT FILMED

PAGE ii INTENTIONALLY BLANK

FOREWORD

This handbook was written by Peter A. Lowry of NASA Lewis Research Center. Many other people were involved in helping compile and produce the final version. Thanks goes to everyone involved and a special thanks for their extra effort and help to

Robert Alexovich, Analex Corporation
Robert A. Bauer, NASA Lewis Research Center
S. Joseph Campenella, Comsat Laboratories
William Cashman, GE Astro-Space
Thom A. Coney, NASA Lewis Research Center
John Graebner, GE Astro-Space
Richard Moat, Motorola
Larry Palmer, Comsat Laboratories
Mark S. Plecity, NASA Lewis Research Center
Carol A. Vidoli, NASA Lewis Research Center

For additional information regarding this handbook or the ACTS Experiments Program please contact

ACTS Experiments Office
ATTN: Mark S. Plecity, MS 54-6
NASA Lewis Research Center
21000 Brookpark Road
Cleveland, OH 44135
(216) 433-2012

PRECEDING PAGE BLANK NOT FILMED

PAGE iv INTENTIONALLY BLANK

CONTENTS

Section | Page

A. ACTS SYSTEM OVERVIEW

B. SPACECRAFT AND GROUND TERMINAL HARDWARE AND NETWORK CONTROL SOFTWARE

PRECEDING PAGE BLANK NOT FILMED

PAGE VI INTENTIONALLY BLANK

Section	Page

Section	Page

APPENDIX A - ACRONYMS

ACTS	Advanced Communications Technology Satellite
BBP	baseband processor
BPSK	binary phase-shift keying
CMOS	complementary metal oxide semiconductor
CONUS	continental United States
CR&T	command, ranging, and telemetry
DAMA	demand-assigned multiple access
EIRP	effective isotropic radiated power
ECL	emitter-coupled logic
FDM	frequency-division multiplexing
FDMA	frequency-division multiple access
IBOW	inbound orderwire
KBH	Ka-band beacon high frequency
KBL	Ka-band beacon low frequency
MCP	multibeam communications package
MOSAIC	Motorola oxide self-aligned implanted circuits
MSM	microwave switch matrix
OBOW	outbound orderwire
PCM	pulse code modulation
QPSK	quaternary phase-shift keying
RCSA	receiving coaxial switch assembly
RF	radio frequency
SMSK	serial minimum-shift keying
TCSA	transmitting coaxial switch assembly
TDM	time-division multiplexing
TDMA	time-division multiple access
TT&C	telemetry, tracking, and command

TWTA	traveling-wave tube amplifier
UFB	uplink fade beacon
WIRS	waveguide input redundancy switch
WORS	waveguide output redundancy switch

APPENDIX B - BEACONS

INTRODUCTION

One of the features of ACTS is its ability to adjust for adverse atmospheric conditions by using burst rate reduction and encoding (Forward Error Correction-FEC) of its digital communications signals. This adaptive feature enhances the reliability of the communications link during rain fades and provides maximum efficiency during clear weather.

Beacons are provided aboard the spacecraft at 20.2 and 27.5 GHz for monitoring uplink and downlink signal fades. The beacon signals can be used to analyze the effects of rain, atmospheric disturbances, and other propagation phenomena. As was mentioned in section A (Spacecraft Bus, Command Ranging, and Telemetry Subsystem) the 20.2 GHz beacons are also used to transmit telemetry information from the spacecraft to the NASA Ground Station.

ACTS COMMAND, RANGING, AND TELEMETRY (CR&T) SYSTEM OVERVIEW

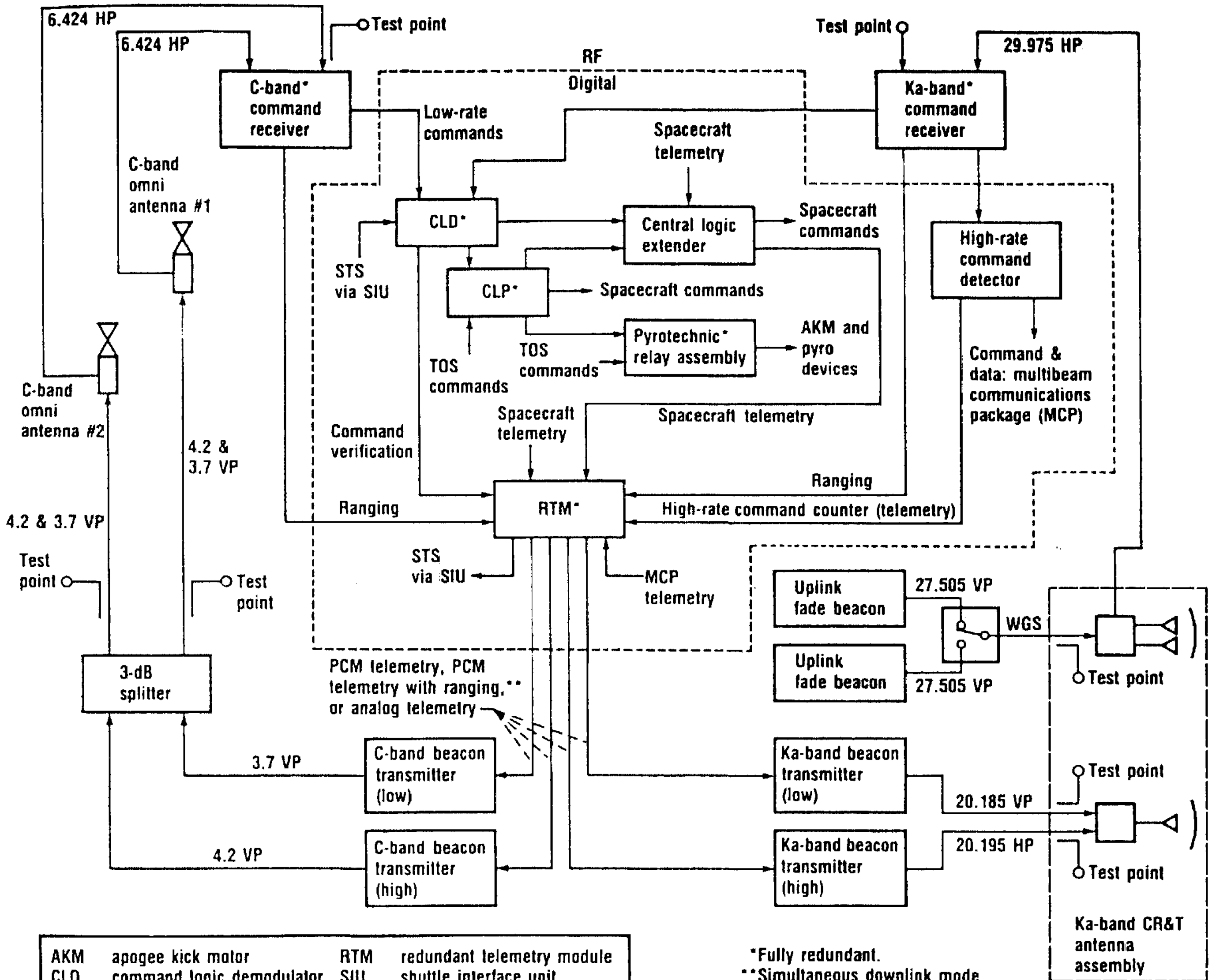
The beacons are part of the command, ranging, and telemetry subsystem. A general overview of this subsystem is presented first, and then, detailed beacon information is presented to assist an experimenter in determining the link budget for an experiment using the beacons. The CR&T subsystem (fig. 1) can be divided into three functional areas. Two of the areas operate at radiofrequencies (RF), and one operates at baseband.

The two RF systems are comprised of C- and Ka-band receivers and transmitters. C-band commands are transmitted throughout the transfer and drift orbit phase after launching the satellite, and when placing the satellite into geosynchronous orbit. C-band communications are also used at geosynchronous altitudes should the Ka-band CR&T link become disabled. Typically, the Ka-band CR&T link is used during everyday operations after the spacecraft is deployed and on station.

The digital baseband portion is indicated within the dashed line and performs the command/ranging and telemetry processing. This system is divided functionally between the low-rate commands and the high-rate commands. The low-rate spacecraft bus commands control positioning and attitude of the satellite. The high-rate commands control the normal operations of the communications payload. Only the Ka-band CR&T subsystem can control the operations of the communications subsystem.

The downlink telemetry data are compiled by the redundant telemetry module. The redundant telemetry module generates subcarriers at 14.5-, 19- or 27.8-, unmodulated 32-, and 64-kHz. The types of information riding on these subcarriers are analog telemetry, digital pulse-code modulated telemetry (e.g., temperature readings, voltage levels, etc.), ranging, and command verification.

The beacon antennae provide coverage to the continental United States (CONUS) and are located on the face panel of the satellite (fig. 2). The 20.2 GHz reflector is the smaller of the two and measures approximately 11" x 6.5" while the 27.5 GHz reflector is approximately 13" x 7.5". Both are configured



AKM	apogee kick motor	RTM	redundant telemetry module
CLD	command logic demodulator	SIU	shuttle interface unit
CLP	central logic processor	STS	Space Transportation System
HP	horizontal polarization	VP	vertical polarization
PCM	pulse-code modulated	WGS	waveguide switch

Figure 1.—Function block diagram of CR&T subsystem. (All frequencies are in gigahertz.)

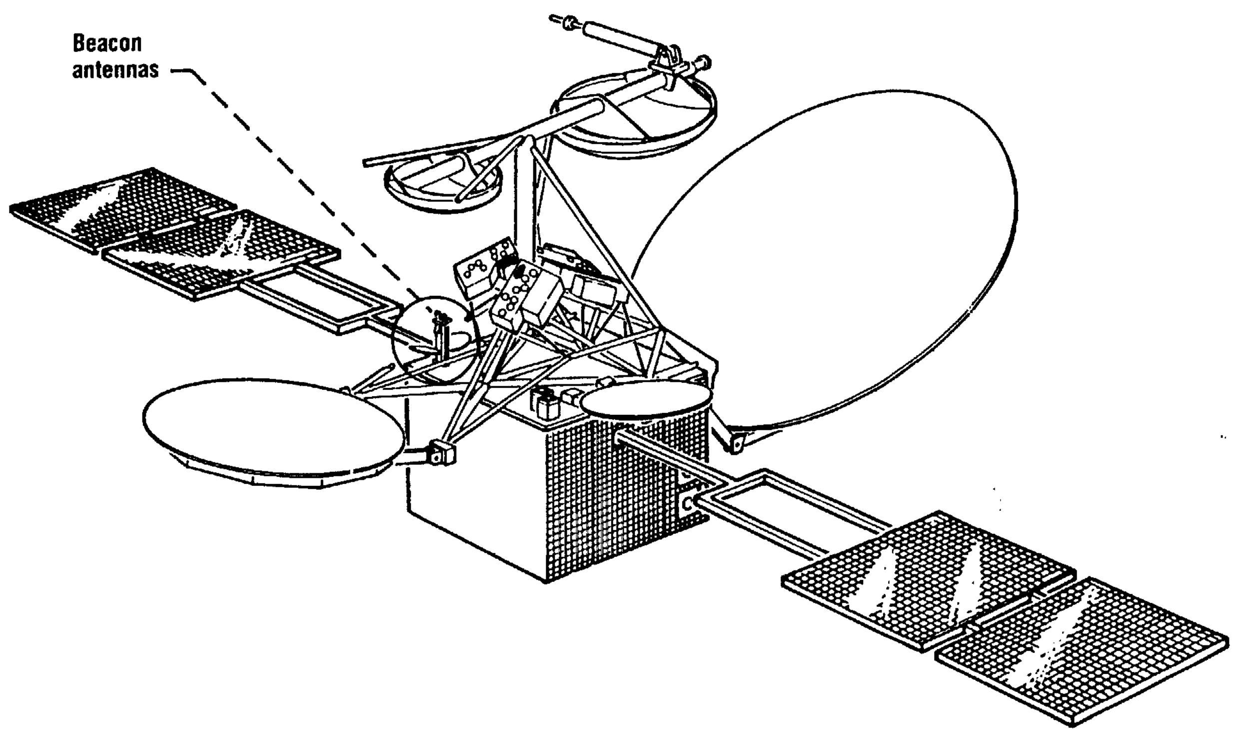


Figure 2.—Location of beacon antenna assembly on Advanced Communications Technology Statllite.

in an elliptical offset fashion. The beacon antenna assembly in figure 3(a) shows the two reflectors and their offset rectangular feeds.

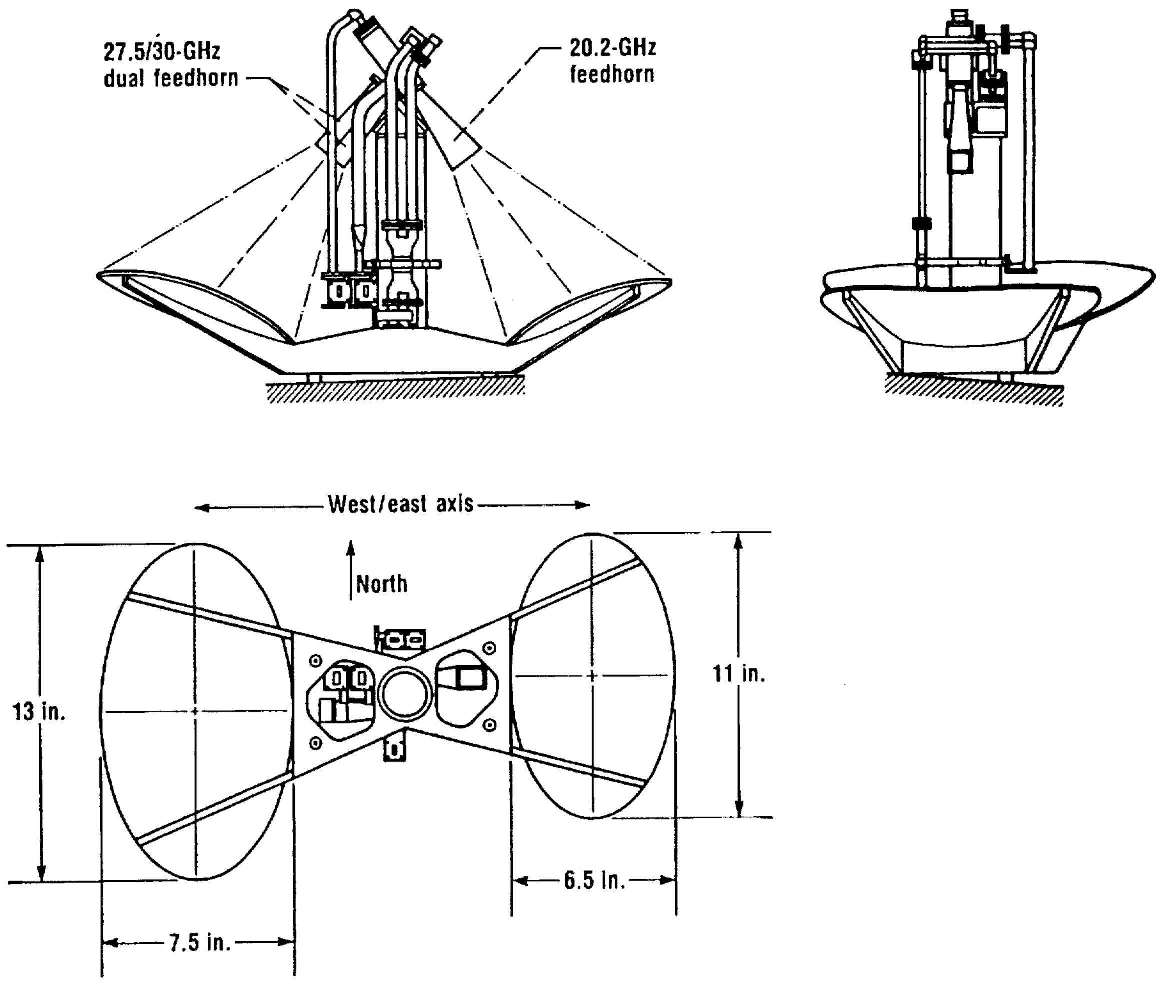
The two 20.2-GHz (downlink frequency) beacon signals are cross-polarized to each other. Only one of two signals is usually present. The large reflector transmits at 27.5 GHz and receives at 30 GHz (uplink frequencies). These transmitted and received signals are also cross-polarized.

KA-BAND (ON-STATION) BEACON CHARACTERISTICS AND FREQUENCIES

In the normal mode of operation, one of the 20.2-GHz beacon carrier signals will be modulated by the 32-kHz and the 64-kHz subcarriers. The 32-kHz subcarrier is used as a placeholder in the subcarrier PCM and PCM dwell modes, and is unmodulated. It is used to maintain the power of the modulated carrier at the same level as in the simultaneous Ranging/PCM mode, which is approximately 3 dB below the unmodulated carrier level. The 64-kHz subcarrier carries the PCM telemetry from the spacecraft bus (housekeeping) and the Multibeam Communications Package (MCP), and also carries command verification data. Fade measurements at the downlink frequency (20.2 GHz) are practically unaffected by the beacon modulation in the operational telemetry modes or by the contents of the telemetry data.

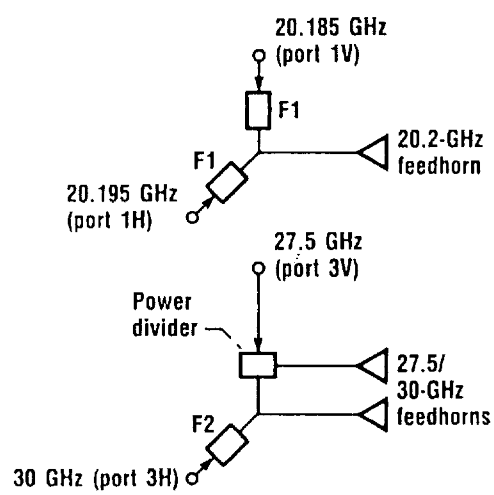
In geosynchronous orbit, the Ka-band telemetry beacons will be phase modulated in one of the following modes. The occupied signal bandwidth will be from 10 to 100 kHz. The modulation levels have been set to provide constant power in the carrier central line.

Mode	Description
1. Two subcarriers, one at 32 kHz and the other at 64 kHz.	The 64 kHz subcarrier is modulated to a peak deviation of $\pi/2$ radian with 1024-bps PCM data that uses a biphase-L format. The 32 kHz subcarrier is unmodulated, serving as a power place-holder when ranging is not active. The two subcarriers each cause a peak carrier phase deviation of 0.72 radian ±10%, and they are linearly combined.
2. A frequency-modulated 14.5 kHz subcarrier with a peak deviation of 1.088 kHz.	The subcarrier is modulated with analog data that has been band-limited using a 220-Hz low-pass filter. The subcarrier will cause a peak phase deviation of 1.0±0.1 radians of the carrier.



(a) Layout of antenna.

Filter requirements for meeting baseline specifications:
F1—40-dB minimum suppression of 27.5- to 30.6-GHz band
F2—35-dB minimum rejection of 27.5 GHz
Port isolation (ports 1V–1H)— ≥ 35-dB isolation in 20.18- to 20.20-GHz band



(b) Block diagram of feed assembly.

Figure 3.—Diagrams of Ka-band CR&T antenna.

3. A sequence of ranging tones with values of 35.4 Hz, 283.4 Hz, 3968.2 Hz, and 27.777 kHz. The three lower frequency tones are frequency modulated on a 19-kHz subcarrier, with a deviation of 1 kHz. Both the 27.777 and 19 kHz are approximately square waves. The ranging tones will cause a peak phase deviation of 0.50±0.05 radian of the carrier. Simultaneously, PCM telemetry is provided on the 64-kHz subcarrier, as in (1). The 32-kHz subcarrier is not present in this mode.

Tables I and II present the frequency and modulation data, as well as other characteristics of the 27.5 GHz and the two 20.2 GHz beacons. Table III provides beacon phase noise information.

TABLE I: CHARACTERISTICS OF BEACON SIGNALS

Characteristic	Uplink fade beacon; 27.5 GHz, unmodulated carrier	Downlink telemetry beacons; 20.2 GHz, modulated carrier
Carrier Frequency at beginning of life, GHz ± MHz	27.505 ± 0.5	20.185 ± 0.3 (V-Pol) 20.195 ± 0.3 (H-Pol)
Measured beacon frequencies from box and subsystem testing of the flight hardware, GHz	UFB #1 - 27.504973 UFB #2 - 27.505028	KBL - 20.185013 KBH - 20.194897
Frequency Stability, ppm: At any one temperature over -10 to 42°C	±10 over 2 years 4 pk. to pk. in 24 hr.	
Operating Temperature, °C	-5 to 36	-5 to 39
Minimum RF Power at end of life, dBm	19.0	22.5
Maximum Output Power Stability, dB	±1 over 24 hr. ±2 over 2 yr.	±0.5 over 24 hr. ±1.5 over 2 yr.
Minimum Effective Isotropic Radiated Power for fade measurements, dBW	15.5	17.5

TABLE II: FREQUENCY AND MODULATION DATA FOR DOWNLINK BEACON SUBCARRIERS

(FM = Frequency Modulation)

Subcarrier Type	Modulation frequency, kHz	Peak deviation	Data rate, bps
Pulse-code-modulated (PCM) telemetry:			
Unmodulated[a]	32	--	--
Biphase-L phase-shift keyed[b]	64	1.57 rad	1024
Analog telemetry (FM direct)	14.5	1.1 kHz	—
Ranging Tones:[c]			
FM subcarrier[d]	19	1 kHz	--
FM direct	27.777	1 kHz	--

[a]Replaces ranging tones to keep carrier power constant.
[b]Contains housekeeping, multibeam communications package and command verification data.
[c]Low-frequency ranging tones modulate 19 kHz subcarrier; high-frequency ranging tone modulates 27.777 kHz subcarrier.
[d]Tones from 35 Hz to 4 kHz.

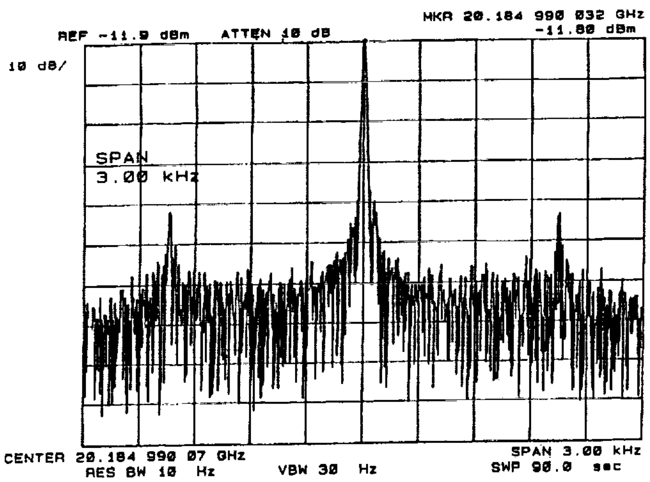
TABLE III: BEACON PHASE NOISE

Frequency away from carrier, Hz	Phase Noise, dBc/Hz[a]	
	Uplink Fade Beacon (27.5 GHz)	Downlink Beacons (20.185 or 20.195 GHz)
50	-49	-51
100	-58	-61
200	-65	-68
300	-69	-72
400	-73	-76
1000	-76	--
3000	-80	--
10000	-92	-92

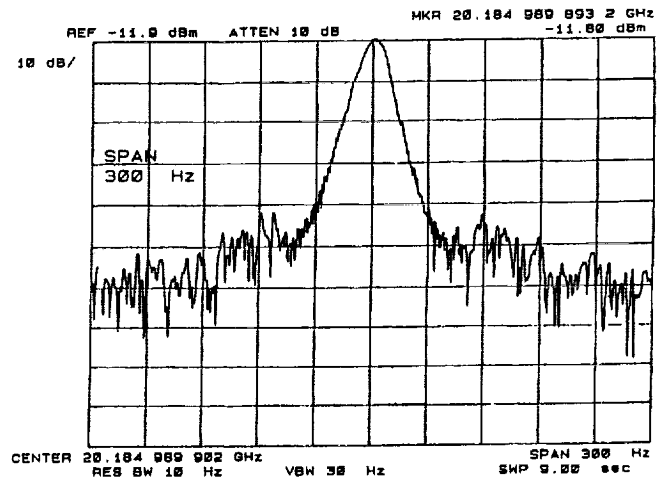
[a]dBc/Hz = decibels referenced to carrier power level in 1 Hz bandwidth.

SPECTRAL PLOTS

Various spectral plots for the primary modes of the telemetry beacons are presented in figures 4 to 7. These plots were made during box and subsystem testing of flight hardware at GE Astro. Plots during normal operations are presented in figures 4 and 5 and show the main carrier and the resulting side-bands from the PCM. Figures 4(a) and (b) show the 20.185 GHz beacon which is also referred to as the Ka-band Low, or KBL beacon, at spans of 3 kHz and 300 Hz, respectively. Figures 5(a) to (d) show the 20.195 GHz beacon which is referred to the Ka-band High, or KBH beacon, at spans of 200 kHz, 20 kHz, 3 kHz, and 300 Hz, respectively.

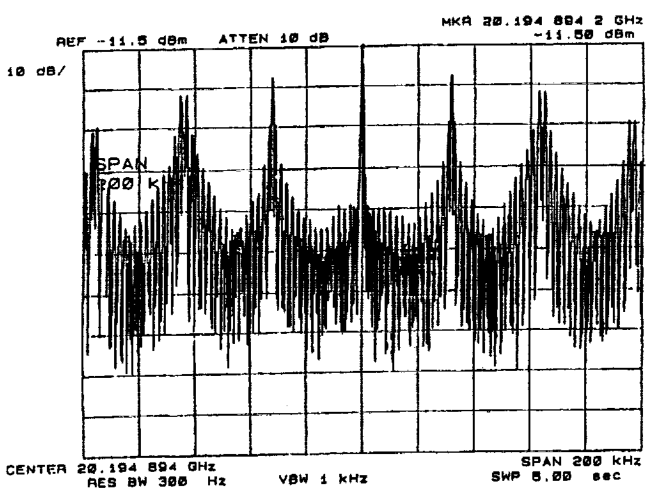


(a) RTM 2, PCM operational, 3 kHz span.

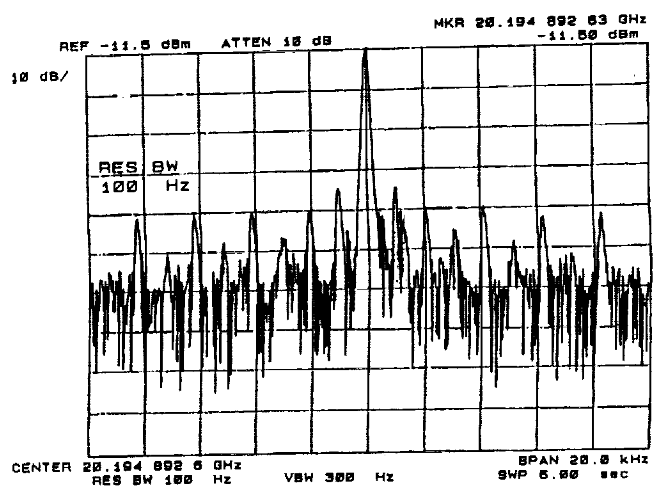


(b) RTM 2, PCM operational, 300 Hz span.

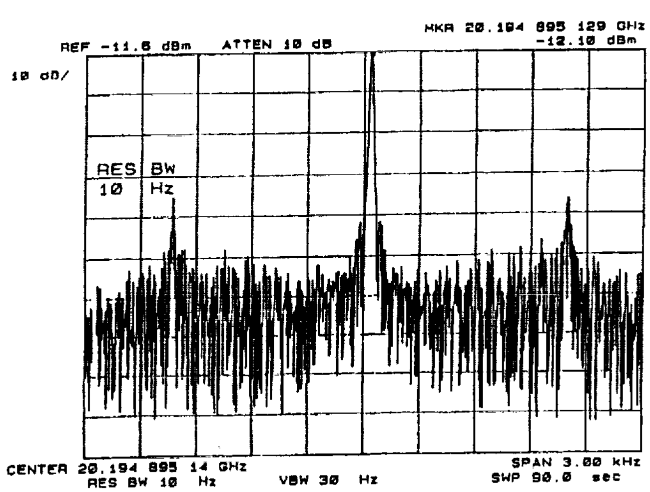
Figure 4.—20.185 GHz (KBL) beacon spectral plots.



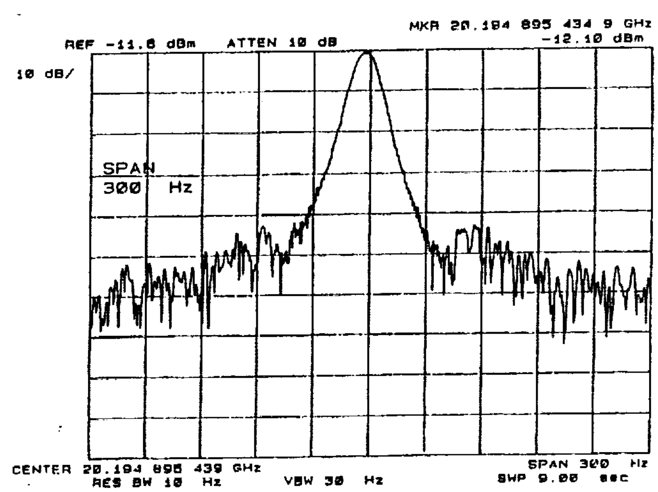
(a) RTM 1, PCM operational, 200 kHz span.



(b) RTM 1, PCM operational, 20 kHz span.



(c) RTM 1, PCM operational, 3 kHz span



(d) RTM 1, PCM operational, 300 Hz span.

Figure 5.—20.195 GHz (KBH) beacon spectral plots.

Ranging will be conducted four days per week for a period of approximately 5 min every 2 hr. It will be conducted at predetermined times so that it can easily be correlated with any glitches observed in fade measurements. During ranging, the 32-kHz subcarrier is replaced with the 27.8-kHz ranging tone approximately 54 sec of each minute. Three spectral responses of the Ka-band High (20.195 GHz) beacon during this mode are shown in figures 6(a) to (c) at spans of 200 kHz, 3 kHz, and 300 Hz, respectively. During the remainder of the ranging period (i.e., about 6 sec of each minute), the 19-kHz subcarrier, which contains the three low-frequency tones, modulates the carrier. Only one tone will be transmitted at a time.

Fade measurements at the uplink frequency (27.5 GHz) are undisturbed by modulation, but they are available only for the vertical polarization. Figures 7(a) and (b) are spectral responses of the 27.5 GHz beacon referred to as the uplink fade beacon, or UFB at spans of 200 kHz and 3 kHz, respectively.

LINK BUDGET CALCULATIONS

Table IV provides the formulas and maximum losses to carrier power resulting from the modulation of the beacons.

TABLE IV: REDUCTION OF THE UNMODULATED CARRIER POWER DUE TO PHASE MODULATION

Formulas

For single subcarrier or tone loss:

$$\text{Loss} = -20 \log[J_0(\theta)]$$

For two subcarriers or tone losses:

$$\text{Loss} = -20 \log[J_0(\theta_1) J_0(\theta_2)]$$

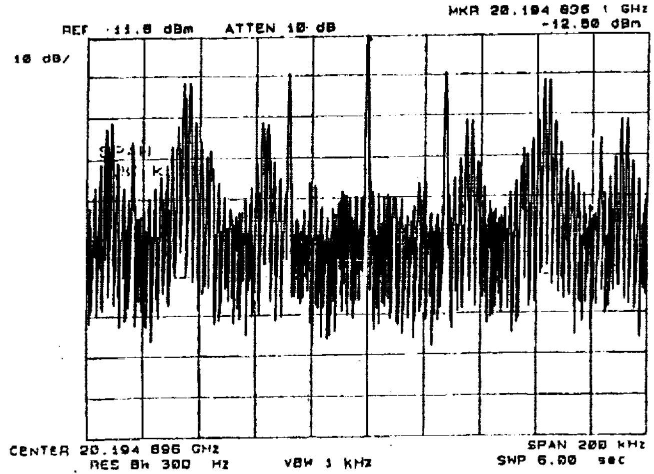
where $J_0(\theta)$ is the zero-order Bessel function of the first kind and θ_i is the radian modulation index.

Carrier Power Losses

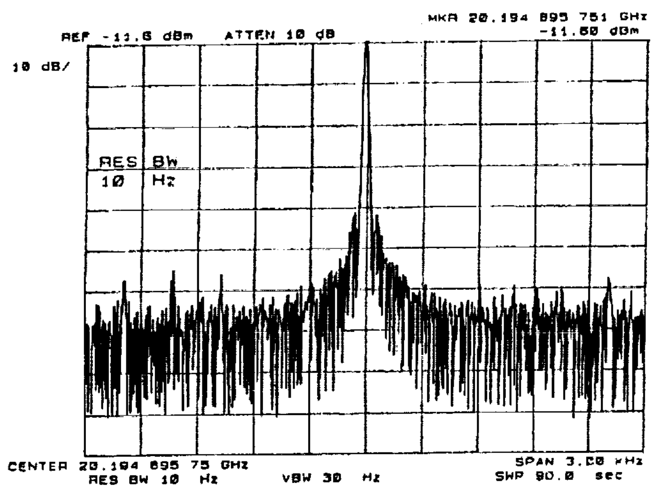
Source of modulation	Number of subcarriers	Peak deviation, rad	$J_0(\theta_i)$	Maximum modulation loss, dBc[a]
Ranging	1	1.1	.072	-2.9
Analog telemetry	1	1.1	.072	-2.9
Pulse-code-modulated telemetry	2	0.83 each	0.835 each	-3.1
Ranging or PCM	2	0.525, 0.83	0.932, 0.835	-2.2

[a]dBc = dB referenced to the carrier power level

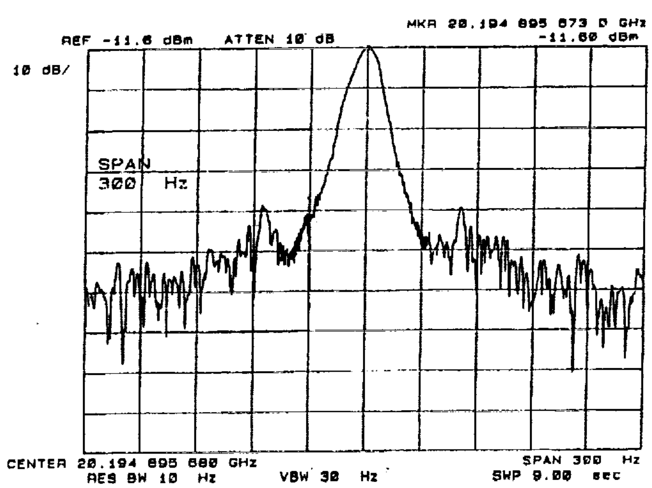
Figure 8 shows the transmitter antenna gains for the continental United States.



(a) 200 kHz span.

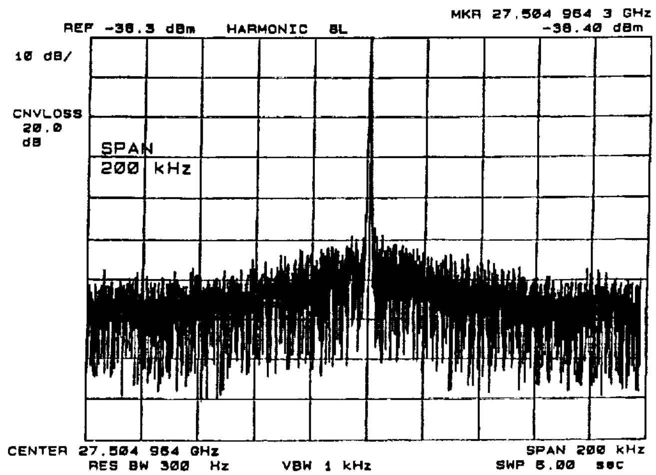


(b) 3 kHz span.

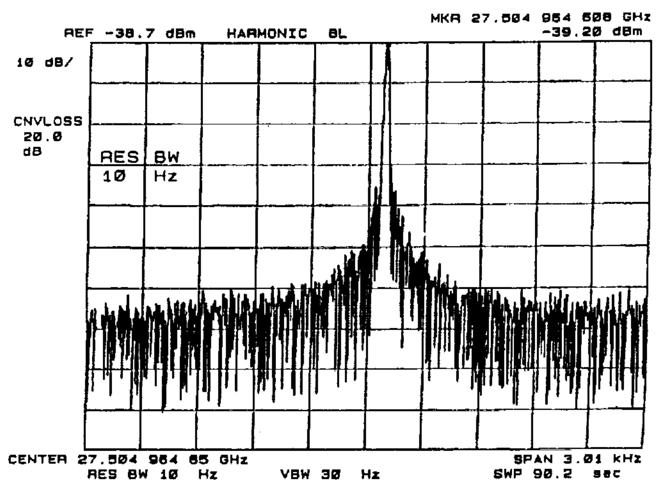


(c) 300 kHz span.

Figure 6.—Spectral response - 20.195 GHz with simultaneous ranging (RTM 1, 27.7 kHz ranging tone, PCM).



(a) 200 kHz span.



(b) 3.01 kHz span.

Figure 7.—Spectral response - (27.5 GHz UFB 1).

By using standard geometric relationships, the user can compute the range to his or her receiver. Once the range (L) is known, the free-space loss can be computed from the equation:

$$L_{fs}(\mathrm{dB}) = 20 \log \left(\frac{4\pi LF}{c} \right)$$

where:

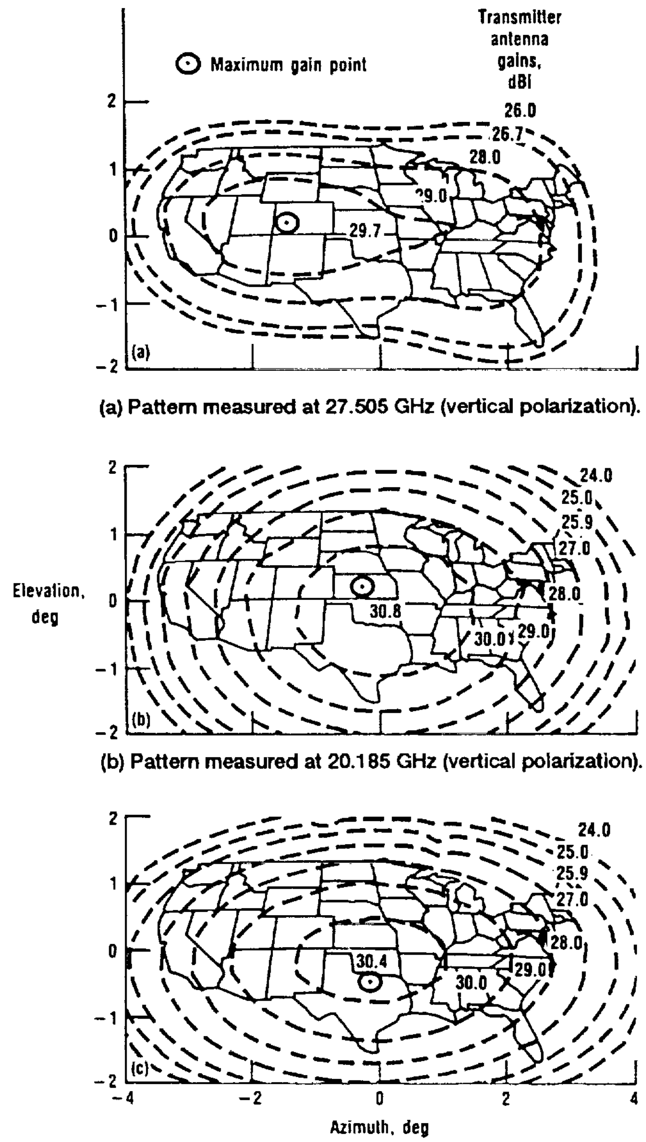
L = satellite to earth-station distance

F = carrier frequency

c = the speed of light

The necessary parameters can now be determined in calculating a link budget specific to an experimenter's site. The beacon frequency and power level are obtained from Table I, the modulation losses from Table IV, and the transmitter antenna gain from figure 8. The received power level at the experimenter's location can be obtained from the range equation. Further details to link calculations can be found in a textbook on satellite communications.

Table V contains the downlink budgets for the beacons at the nominal edge of CONUS coverage, with the exception of the first column, which provides data at the master control station in Cleveland, Ohio. The frequency used for telemetry and ranging (TLM and RNG), and fade measurements, is 20.2 GHz.



(a) Pattern measured at 27.505 GHz (vertical polarization).

(b) Pattern measured at 20.185 GHz (vertical polarization).

(c) Pattern measured at 20.195 GHz (horizontal polarization).

Figure 8.—Uplink fade beacon and Ka-band beacon transmitter radiation patterns of Ka-band CR&T antenna assembly. Satellite longitude, 100° W; antenna boresight: longitude, 96.4° W; latitude, 35.9° N; azimuth, –0.495°; elevation, –5.897°.

TABLE V: Ka-BAND DOWNLINK BUDGETS

Parameter		TLM and RNG (NGS)	20.2 GHz fade	27.5 GHz fade
Beacon Xmtr power (end of life, 2 yr. values)	dBW	-7.50	-7.50	-10.00
Coupling and cabling loss	dB	-0.80	-0.80	-0.90
Antenna gain	dBi	27.90	25.90	26.80
Min. satellite EIRP	dBW	[a]19.60	[b]17.60	[b]15.90
Free-space (Path) loss	dB	-210.10	-209.90	-212.60
Rain loss (G/T)	dB	-9.00	Clear weather reference for fade measurements	
Atmospheric loss	dB	-0.40	-0.40	-0.60
Polarization loss	dB	-0.10	-0.20	-0.10
Ground station pointing loss	dB	-0.20	-0.20	-0.40
Ground station G/T	dBi/K	26.70	19.10	20.00
Boltzman constant	dB-Hz/K/W	-228.60	-228.60	-228.60
Received C/N_o	dBW	55.10	54.60	50.80
Modulation loss	dB	--	-3.1	0.0
Required C/N_o density: PCM	dB-Hz	51.00	NA	NA
System margin	dB	4.10	NA	NA
Required C/N_o density: analog	dB-Hz	49.60	NA	NA
System Margin	dB	5.50	NA	NA
Required C/N_o density: ranging	dB-Hz	51.10	NA	NA
System Margin	dB	4.00	NA	NA

[a] EIRP level at Cleveland, Ohio
[b] Minimum EIRP at edge of CONUS coverage, except for South Florida